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(74) Agents: RAUFER, Colin; Raytheon Company, 2000 East El Segundo Boulevard, P.O. Box 902, El Segundo, CA 90245 et al. (US).

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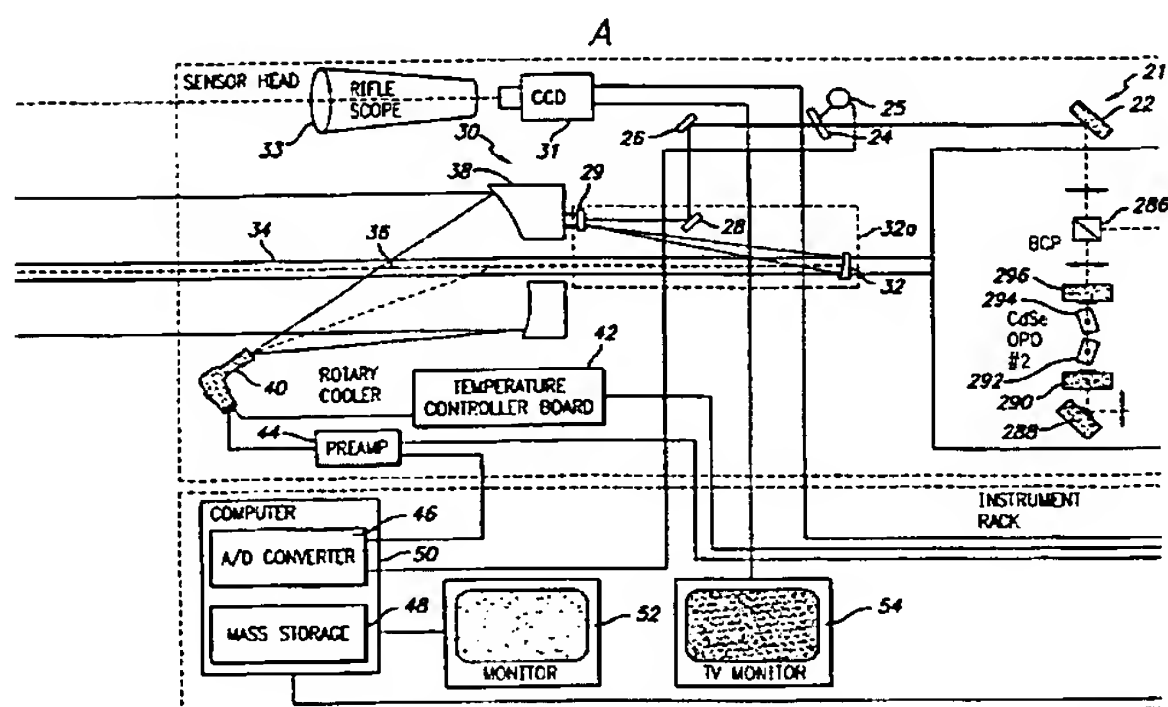
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(71) Applicant: RAYTHEON COMPANY [US/US]; 2000 East El Segundo Boulevard, P.O. Box 902, El Segundo, CA 90245 (US).

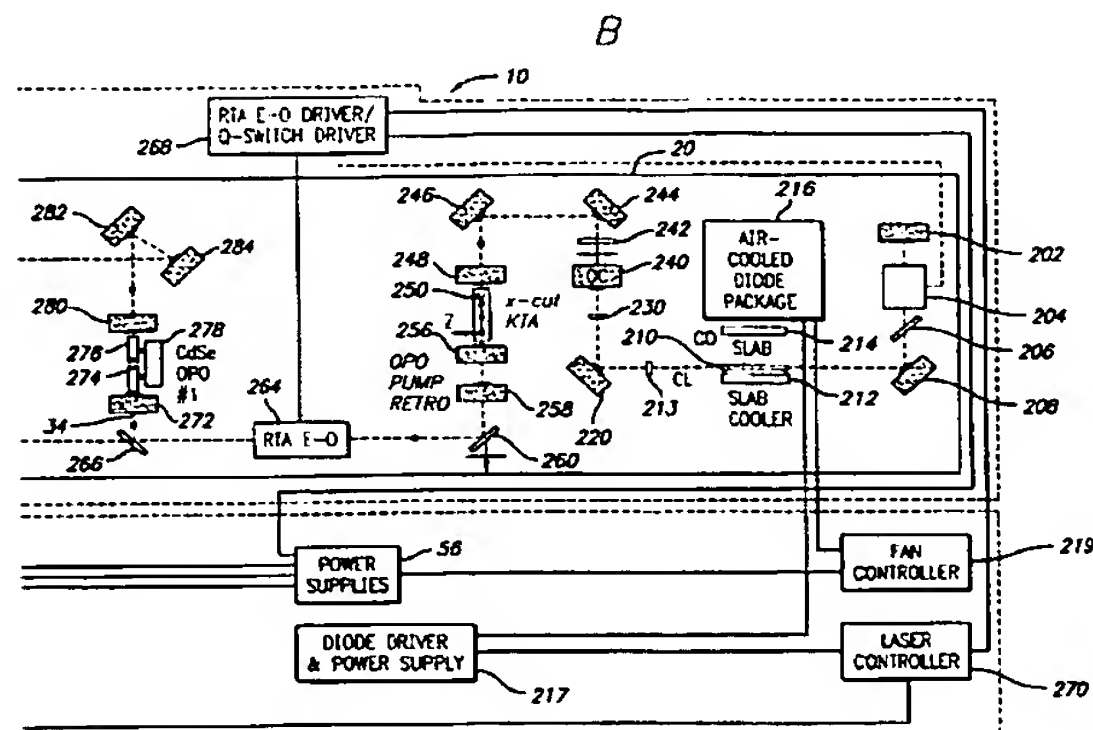
(72) Inventor: FUKUMOTO, Joseph, M.; 6443 Chartres Drive, Rancho Palos Verdes, CA 90275 (US).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SYSTEM AND METHOD FOR PROVIDING COLLIMATED ELECTROMAGNETIC ENERGY IN THE 8-12 MICRON RANGE



(57) Abstract: A novel and efficient system and method for providing an output beam of collimated energy in the 8-12 micron range. The solid state system includes a pump laser (210) for providing an input beam and an OPO (250) using an x-cut potassium titanyl arsenate crystal for shifting the input beam from the first frequency to a second frequency. A second optical parametric oscillator (271) is included for shifting the beam from a second frequency to a third frequency. The second optical parametric oscillator (271) uses a cadmium selenide crystal. A tuning mechanism with an associated controller is provided to tune the oscillator as needed for a particular application.



**SYSTEM AND METHOD FOR PROVIDING COLLIMATED
ELECTROMAGNETIC ENERGY IN THE 8 - 12 MICRON RANGE**

5

CROSS-REFERENCE TO RELATED APPLICATIONS

10 This application is a continuation-in-part of U.S. Patent Application no. _____, entitled MONOLITHIC SERIAL OPTICAL PARAMETRIC OSCILLATOR filed _____, by J. M. Fukumoto (Atty. Docket No. PD 99W073). In addition, this application relates to copending applications nos. _____ and _____ entitled SYSTEM AND METHOD FOR
15 SENSING ATMOSPHERIC CONTAMINANTS USING TRANSMITTER WITH DUAL OPTICAL PARAMETRIC OSCILLATORS AND RECEIVER FOR SAME, filed _____ by J. M. Fukumoto and VARIABLE PATH LENGTH PASSIVE Q SWITCH, filed _____ by J. M. Fukumoto (Atty. Docket Nos. PD 00W057 and PD 00W058, respectively).

20

BACKGROUND OF THE INVENTION

25 Field of the Invention:

 The present invention relates to solid state lasers. More specifically, the present invention relates to solid state lasers operative in the 8 - 12 micron range.

30

Description of the Related Art:

Lasers are currently widely used for communication, research and development, manufacturing, directed energy and numerous other applications. For many applications, the energy efficiency, power and lightweight of solid state lasers makes these devices particularly useful. Solid state lasers currently lase in the range of one to three microns.

For certain applications, there is a need to reach longer laser operating wavelengths. In particular, there is interest in the 8 - 12 micron (μm) region.

Several groups have demonstrated wavelength conversion to this region using various solid-state lasers, or the output from optical parametric oscillators (OPOs) as pump sources for longer wavelength OPOs and difference frequency generation crystals. See for example: 1) S. Chandra, T. H. Allik, G. Catella, R. Utano, J. A. Hutchinson, "Continuously tunable 6-14 μm silver gallium selenide optical parametric oscillator pumped at 1.57 μm ," Appl. Phys. Lett. **71**, 584-586 (1997); 2) T. Allik, S. Chandra, D. M. Rines, P. G. Schunemann, J. A. Hutchinson, and R. Utano, "7-12 μm generation using a Cr, Er:YSGG pump laser and CdSe and ZnGeP₂ OPOs," in *Advanced Solid State Lasers, OSA Trends in Optics and Photonics* (Optical Society of America, Washington, D. C., 1997), Vol. 10, pp. 265-266; and 3) R. Utano and M. J. Ferry, "8-12 μm generation using difference frequency generation in AgGaSe₂ of a Nd:YAG pumped KTP OPO," in *Advanced Solid State Lasers, OSA Trends in Optics and Photonics* (Optical Society of America, Washington, D. C., 1997), Vol. 10, pp. 267-269.

One approach involved the use of a flashlamp pumped Cr, Er:YSGG laser emitting at 2.79 microns to pump a cadmium selenide (CdSe) OPO. This approach has been represented as being effective to yield a tunable 8 - 12 micron output. Unfortunately, the poor overall electrical efficiency of the Cr, Er:YSGG pump laser, together with its fairly long (50 ns) output pulse width, result in a less than optimal

CdSe OPO pump source.

Hence, a need remains in the art for an efficient, tunable system or method for converting the output of a typical 1 - 3 μm laser to the 8 - 12 μm range.

5

SUMMARY OF THE INVENTION

The need in the art is addressed by the solid state laser of the present invention.

10 The inventive laser includes a pump laser for providing an input beam. An optical parametric oscillator (OPO) provides a first stage which shifts the input beam from the first frequency to a second frequency. In accordance with the present teachings, a second stage mechanism is included for shifting the beam from a second frequency to a third frequency.

15 In the illustrative embodiment, the mechanism for shifting the beam from the second frequency to the third frequency is an OPO using a cadmium selenide crystal. In the illustrative embodiment, the input beam is a one-micron beam and the third frequency is in the range of 8 - 12 microns. In the best mode, the first stage OPO includes a crystal which is x-cut potassium titanyl arsenate.

20 The invention provides a novel and efficient system and method for providing an output beam of collimated energy in the 8 - 12 micron range.

BRIEF DESCRIPTION OF THE DRAWINGS

25

Fig. 1 is a block diagram of an illustrative implementation of a remote chemical sensing system incorporating the teachings of the present invention.

Fig. 2 is a block diagram of the laser transmitter of Fig. 1.

Figs. 3a - c are diagrams which illustrate the design and operation of the passive Q switch utilized in preferred embodiment of the transmitter of Fig 2. Fig. 3a show a side view of the switch.

5 Figs. 3b and 3c depict side and top views, respectively, of a wedge of the passive Q switch of the present invention.

Fig. 4 is a simplified diagram illustrative of the operation of the solid state lasers utilized in the transmitter of the present invention.

Fig. 5 is a diagram showing the receiver of the system of Fig. 1 in greater detail.

10

DESCRIPTION OF THE INVENTION

15 Illustrative embodiments and exemplary applications will now be described with reference to the accompanying drawings to disclose the advantageous teachings of the present invention.

While the present invention is described herein with reference to illustrative embodiments for particular applications, it should be understood that the invention is not limited thereto. Those having ordinary skill in the art and access to the teachings
20 provided herein will recognize additional modifications, applications, and embodiments within the scope thereof and additional fields in which the present invention would be of significant utility.

Fig. 1 is a block diagram of an illustrative implementation of a remote chemical sensing system incorporating the teachings of the present invention. The system
25 includes a laser transmitter 20 which outputs a reference beam and a probe beam as discussed more fully below.

Fig. 2 is a block diagram of the laser transmitter of Fig. 1. The transmitter includes a diode pumped laser 200 having a rear high reflector 202. The gain medium for the laser is a neodymium YAG (Nd:YAG) slab 210. The oscillating beam 211

output by the slab 210 is directed to the rear high reflector 202 by a turning mirror 208.

As shown in Fig. 1, an electro-optic Q switch 204 and a linear polarizer 206 may be positioned between the rear high reflector 202 and the turning mirror 208. However, as discussed more fully below, in the best mode, a novel passive Q switch 230 can be
5 used as an alternative. Accordingly, the electro-optic Q switch 204 and a linear polarizer 206 are shown in phantom in Fig. 1 to indicate that these elements are associated with an optional alternative implementation.

Returning to Fig. 2, in the preferred embodiment, the laser 200 is a neodymium YAG laser. The laser 200 can also use Nd:YLF or Nd:YVO₄ as the gain medium,
10 depending on the particular pulse energy, pulse width, and pulse repetition rate required. A cooling block 212 is soldered to the Nd:YAG slab 210 to provide cooling as is common in the art. A cylindrical lens 213 is positioned in optical alignment with the slab 210 to optimize the profile of the beam output thereby. The slab 210 is pumped by an array of diodes (not shown) disposed in an air-cooled package 214. A collimated
15 optic 216 is included for collimating and directing the output of the diodes into the laser slab 210 to achieve an optimal pump distribution. In the preferred embodiment, a collimating optic such as that disclosed and claimed in copending U. S. Patent application no. _____ entitled SHAPING OPTIC FOR DIODE LIGHT SHEETS, filed _____ by J. M. Fukumoto *et al.* (Atty. Docket No. PD-
20 99W079), the teachings of which are incorporated herein by reference. Contacts 218 and 219 are provided for the package 214 as shown in the figure.

In the preferred embodiment, the oscillating beam of the slab 210 is directed by a second turning mirror 220 to an output coupler 240 via a passive Q switch 230 of novel design. The passive Q switch 230 is disclosed and claimed in copending U. S.
25 patent application no. _____, entitled _____, filed _____ by J. M. Fukumoto, (Atty. Docket No. PD 00W058) the teachings of which are incorporated herein by reference.

Figs. 3a - c are diagrams which illustrate the design and operation of the passive Q switch utilized in preferred embodiment of the transmitter of Fig 2. Fig. 3a shows a

side view of the switch 230. In accordance with the present teachings, the switch 230 is implemented with first and second identical wedges 232 and 234. In the illustrative embodiment, each wedge is made of $\text{Cr}^{+2}:\text{YAG}$). As shown in Fig. 3a, the first wedge has a slanted surface 236 while the second wedge has a slanted surface 238. The
5 wedges 232 and 234 are mounted to slide relative to each other in a plane parallel to plane of the slanted surfaces 236 and 238 thereof respectively. This sliding of the wedges has the effect of increasing the path length of the switch 230 with respect to the laser alignment axis 211 and beam. As is known in the art, the thickness of the switch 230 determines the laser's hold-off point thereof, i.e., the point at which the
10 switch allows for the beam to pass therethrough. As is well known in the art, the Q switch 230 serves to ensure that the laser beam is output in a short duration pulse of energy.

The wedges 232 and 234 are translated by a suitable mechanical arrangement (not shown). For example, the wedges may be translated by solenoids (not shown) in
15 response to a control signal from the laser controller 270 which is driven by the computer 50. By sliding the wedges 232 and 234 relative to each other, the thickness of the switch 230 may be adjusted. By keeping the wedge separation distance 'd' constant when sliding the wedges, the resonator alignment axis of the beam 211 remains unchanged. This may be important for resonators using curved mirror
20 surfaces sensitive to resonator axis translations. The arrangement of the present invention allows for maintaining precise alignment of the resonator axis while varying the path length, and hence hold-off, through the passive Q-switch material.

Figs. 3b and 3c depict side and top views, respectively, of a wedge of the passive Q switch of the present invention. Figs. 3b and 3c show dimensions of the
25 passive Q switch 230 of the illustrative embodiment. Note that the wedge fabrication specifically calls out crystal orientations in order to provide optimum Q switch performance. The laser polarization should be parallel to the [010] axis for best performance. The wedges should be polished and anti-reflection coated in order to minimize the Fresnel losses from the four surfaces.

Returning to Fig. 2, those skilled in the art will recognize the laser 200 as extending from the high reflector 202 to the output coupler 240. In the figures, the short line segment with double arrowheads 241 indicates horizontal polarization and the circle 243 indicates vertical polarization of the beam. The horizontally polarized output from the laser is rotated to the vertical by a half waveplate 242 ($\lambda/2$) so that the KTA optical parametric oscillator (OPO) output at 2.59 μm is vertically polarized for processing by the optical parameter oscillator 250 as discussed more fully below. (This allows high reflectivity of the 2.59 μm wave and wavelength separation of the p-polarized 3.47 μm and 3.76 μm waves at the dichroic beamsplitter (DBS) 260 below.)

Third and fourth turning mirrors 244 and 246 direct the vertically polarized beam output by the laser to the first OPO 250. As described more fully in the above-identified parent application (U.S. Patent Application no. _____, entitled MONOLITHIC SERIAL OPTICAL PARAMETRIC OSCILLATOR filed _____, by J. M. Fukumoto (Atty. Docket No. PD 99W073), the OPO 250 is comprised of an x-cut crystal 251 of potassium titanyl arsenate (KTA), or other suitable material, as a non-linear medium, together with a rear high reflector 248 and output coupler 256. In a standard configuration, the crystal 251 is placed between the high reflector 248 and the output coupler 256. The first OPO 250 can also be operated as an intracavity element to the Nd:YAG laser (not shown) with suitable mirror coatings for the laser and OPO. The OPO serves to shift the frequency of the beam output by the laser 200 from 1.064 microns to 2.59 microns in the illustrative embodiment.

An OPO pump retro-reflector 258 is a high reflector mirror that reflects the unconverted 1.06 micron energy from the OPO 250 back to the OPO 250, such that it has two passes through the crystal 250 for additional nonlinear gain, and passes energy at 2.59 microns.

A polarization and frequency selective dichroic beamsplitter (DBS) 260 transmits secondary emissions from the OPO 250 at 3.47 microns and 3.76 microns

and reflects energy at 2.59 microns to a quarter-wave plate 262. One of ordinary skill in the mirror manufacture art would be able to construct the DBS 260 without undue experimentation. The DBS should be highly reflective to s-polarized light at 2.59 μm at 45° incidence angle and highly transmissive to wavelengths longer than 3.1 μm for p-polarized light at 45° incidence angle.

The 2.59 μm wave is passed through a $\lambda/4$ plate 262 and an RTA electro-optic switch 264 in order to maintain the vertical polarization or to rotate it by 90° so that the 2.59 μm wave can be steered to either of two cadmium selenide (CdSe) optical parametric oscillators as discussed more fully below. This polarization switching can be done at near megahertz repetition rates depending on the repetition rate of the laser. Employing a fixed $\lambda/4$ plate before the switch 264 allows the switch 264 to operate at alternating + and - voltages so that the average voltage on the switch is zero. In addition, lower $\lambda/4$ voltages can be used to avoid breakdown. The switch 264 rotates the plane of polarization in response to a voltage applied by a driver circuit 268 of Fig. 1 under command of a laser controller 270.

A thin film linear polarizer 266 is included to transmit horizontally polarized light and reflect vertically polarized light at 2.59 μm . This is effective to create the reference and probe beams 34 and 36, respectively, as discussed more fully below. The thin film polarizer 266 is fabricated in such a manner as to highly reflect s-polarized 2.59 μm light and highly transmit p-polarized 2.59 μm light. Using the switch 264 and the polarizer 266, the single wavelength converted beam from the laser 200 is used to create the reference beam 34 and the probe beam 36 and to rapidly switch therebetween.

The reference beam is generated by a second OPO assembly 271, while the probe beam 36 is generated by a third OPO 273. In combination with the first stage OPO 250, the second stage OPOs (271 and 273) provide tunable output in the 8 - 12 micron range. The operation of the first and second stage OPOs are best described with reference to the drawing of Fig. 4.

Fig. 4 is a simplified diagram illustrative of the operation of the first and second stage OPOs utilized in the transmitter of the present invention. At the outset, it should be noted that Fig. 4 is illustrative of the operation of the first and second stage OPOs with the exception that the desired primary beam at 8 - 12 microns is shown exiting the rear of the crystal 274'. As discussed more fully below, this arrangement is useful to provide angle tuning without beam displacement with a single crystal. Accordingly, the reflectors are numbered 275 and 277 in Fig. 4 to illustrate that the figure depicts an alternative single crystal arrangement for the first and the second stage OPOs. Hence, the function of the reflectors 275 and 277 in Fig. 4 is implemented by the reflectors 272/280 and 290/296 of Fig. 2.

In any event, as shown in Fig. 4, the first stage OPO 250 (using x-cut KTA in the illustrative embodiment) receives the pump beam (at 1.064 micron in the illustrative embodiment) from the laser 200 and outputs a beam (at 2.59 microns) as discussed above. This beam (at 2.59 microns) serves to pump the crystal 274' of the second stage OPO 271' such that it emits a primary beam along with a secondary emission. In the illustrative embodiment, the crystals 273 and 291 are of cadmium selenide construction which outputs a primary beam at 8 - 12 microns with a secondary emission in the range 3.3 to 3.8 microns in response to a pump beam at 2.59 microns. KTA OPO mirror reflectivities must be maintained to tight specifications to generate the desired beams efficiently as will be appreciated by one of ordinary skill in the art.

Those skilled in the art will appreciate that in Fig. 4, the forward emission of the beam in the range of 3.3 to 3.8 microns and the backward emission of the 8 - 12 micron beam is a result of the coatings on the reflectors 275 and 277. One skilled in the art would appreciate that these mirrors could be coated to output the beam desired for a given application (e.g. the 8 - 12 micron beam) in an optimal direction for a given application and layout without departing from the scope of the present teachings. However, the direction of the beam will affect its displacement as the crystal is tuned as discussed below.

That is, a tilting of the crystal, as depicted in Fig. 2, results in a corresponding change in the wavelength of the output beam. Hence, the OPO may be tuned continuously by tilting the crystal. However, the tilting of the crystal will also result in a displacement of the beam output in the forward direction, i.e. the 3.3 - 308 micron beam in Fig 2. However, the primary beam output in the reverse direction (i.e., the beam at 8 - 12 microns) will not be displaced because this beam is reflected by the second mirror 277 and therefore retraces its path through the crystal. Hence, the effect a displacement in one direction is countered by a corresponding displacement in the opposite direction as the beam retraces its path.

When it is desired to output a spatially stable beam in a forward direction, each crystal 273 and 291 may be segmented into two smaller identical crystals 274/276 and 292/294 respectively. The crystals 274, 276, 292 and 294 are pivotally mounted. The two crystals in each set 274/276 and 292/294 are tilted in opposite directions as shown in Fig. 2. This novel arrangement provides angle tuning without beam displacement. Actuators 278 (shown) and 293 (not shown) provide angle tuning in Fig. 2 in response to the laser controller 270.

Note that in Fig. 2, the first crystal set 273 is seen from a side view while the second crystal set 291 is seen from a top view. This orientation is necessary because, in the illustrative embodiment, the reference beam 34 is vertically polarized and the probe beam is horizontally polarized and the optical parametric oscillators are polarization selective. The two second stage OPO outputs are made precisely co-linear by two final tuning mirrors 282 and 284 and a beam combining prism (BCP) 286.

In accordance with the present teachings, the reference beam is selected to be 'out-of-band' with respect to a chemical to be sensed in the atmosphere while the probe beam is 'in-band'. That is, since the spectra of major chemical agents is known in the 8-11 μm region, probing for a specific agent first requires in-band and out-of-band wavelength setting of the second stage CdSe OPOs. This wavelength setting can be accomplished by a relatively slow and small electro-mechanical motor, or can be

manually set to predetermined angular positions.

Once the second stage OPOs are set to their respective wavelengths (λ_1 , λ_2), the laser 200 and RTA switch 264 can be fired to produce rapidly alternating λ_1 , λ_2 output wavelengths. A major advantage of this approach is that rapidly alternating
5 wavelengths can be produced without the necessity of rapidly rotating crystals, as would be required for angle tuning using one second stage OPO. In addition, vibration isolation of a rapidly oscillating crystal(s) would be a significant concern in a platform that required interferometric stability, such as that of the transmitter laser. Finally, near megahertz switching rates, if required, would be exceeding difficult or
10 impossible to implement mechanically, due to the mass, angular position accuracy, and angular velocity required to angle tune the CeSe crystals at these rates.

Returning to Fig. 1, the beams output by the transmitter 20 are directed by an optical arrangement 21 including a first mirror 22, a sampling beamsplitter 24, a second mirror 26, a third mirror 28, a convex mirror 29 and a concave mirror 32. The convex
15 mirror 29 and concave mirror 32 comprise an off-axis parabolic expansion telescope 32a for the output beam. The optical arrangement 21 outputs the probe beam 34 and a reference beam 36 through an aperture 37 in a single element, off-axis paraboloid 38. Reflections of the probe and reference beams return to the system 10 and are received and focused by the paraboloid 38 onto a detector 40.

20 As mentioned above, the probe beam 36 is in the absorption band of chemical contaminants while the reference beam is out of band. A difference in the return signals for the two beams will indicate whether a chemical cloud is present in the path of the probe beam. That is, if a chemical contaminant cloud is present, it will selectively absorb energy from the in-band probe beam 34, and will subsequently
25 reduce the reflected probe beam energy sensed at the detector 40. In contrast, the reference beam 36 which is not absorbed by the cloud, will be reflected back to the detector 40 without suffering significant attenuation.

In the illustrative embodiment, the detector 40 is a mercury cadmium telluride

(HgCdTe) detector. Nonetheless, those skilled in the art will appreciate that the present invention is not limited to the detector technology employed.

Fig. 5 is a diagram showing the receiver in greater detail. As shown in Fig. 5, the receiver 30 consists of the single element, off-axis paraboloid 38 which is focused
5 onto the cryogenically cooled detector 40. The detector element 40 is a single 0.5 mm diameter HgCdTe element mounted in a rotary cooler. In the preferred embodiment, the microcooler is an integral Stirling engine with the detector directly mounted to the cold finger.

To eliminate the effects of parallax and pointing complexities with separate
10 receiver and transmitter apertures, a hybrid coaxial design is utilized as shown in Fig. 5. A central obscuration of less than 0.5 percent in area is realized from this design and simplifies pointing the sensor unit. An afocal design using two off-axis parabolic sections forms the transmitter beam expander assembly 32a. In the preferred
15 embodiment, the 0.5 mm diameter transmitter beam is expanded 13 times to reduce transmitter divergence to 3 mR. In the preferred embodiment, the receiver and transmitter mirror designs are fabricated from 6061-T6 aluminum alloy and coated with gold for high reflectivities at the 8-12 μm band.

Transmitted energy is measured by sampling a fraction of the laser output with a room temperature HgCdZnTe photodetector 25. Sampling is accomplished by
20 reflection from a beamsplitter surface 24 positioned upstream from the transmitter beam expander assembly 32a.

Returning to Fig. 1, the temperature of the detector 40 is controlled by a conventional temperature controller 42. Detector signals, power and command signals are routed to the sensor head through a umbilical from an instrument rack. The
25 detector 40 outputs a number of electrical signals which are amplified by a preamplifier 44 and digitized by an analog-to-digital (A/D) converter 46. In the illustrative implementation, the A/D conversion is implemented in a computer 50 having memory 48. Those skilled in the art will appreciate that the present teachings are not limited to the signal processing system shown in Fig. 1. Data acquisition is accomplished by

conventional concentration-pathlength (CL) measurements of clouds using returns off of topographic targets. Intensity comparison measurements of the transmitted beam and the received energy are calculated for each laser firing.

Any analog, digital, optical or hybrid circuit may be used to process the signals
5 received by the system 10 without departing from the scope of the present teachings. The computer 50 outputs to a computer monitor 52 or a television monitor 54. The computer may be programmed to process the return signals to extract range data with respect to a cloud of contaminants.

Thus, the present invention has been described herein with reference to a
10 particular embodiment for a particular application. Those having ordinary skill in the art and access to the present teachings will recognize additional modifications, applications and embodiments within the scope thereof.

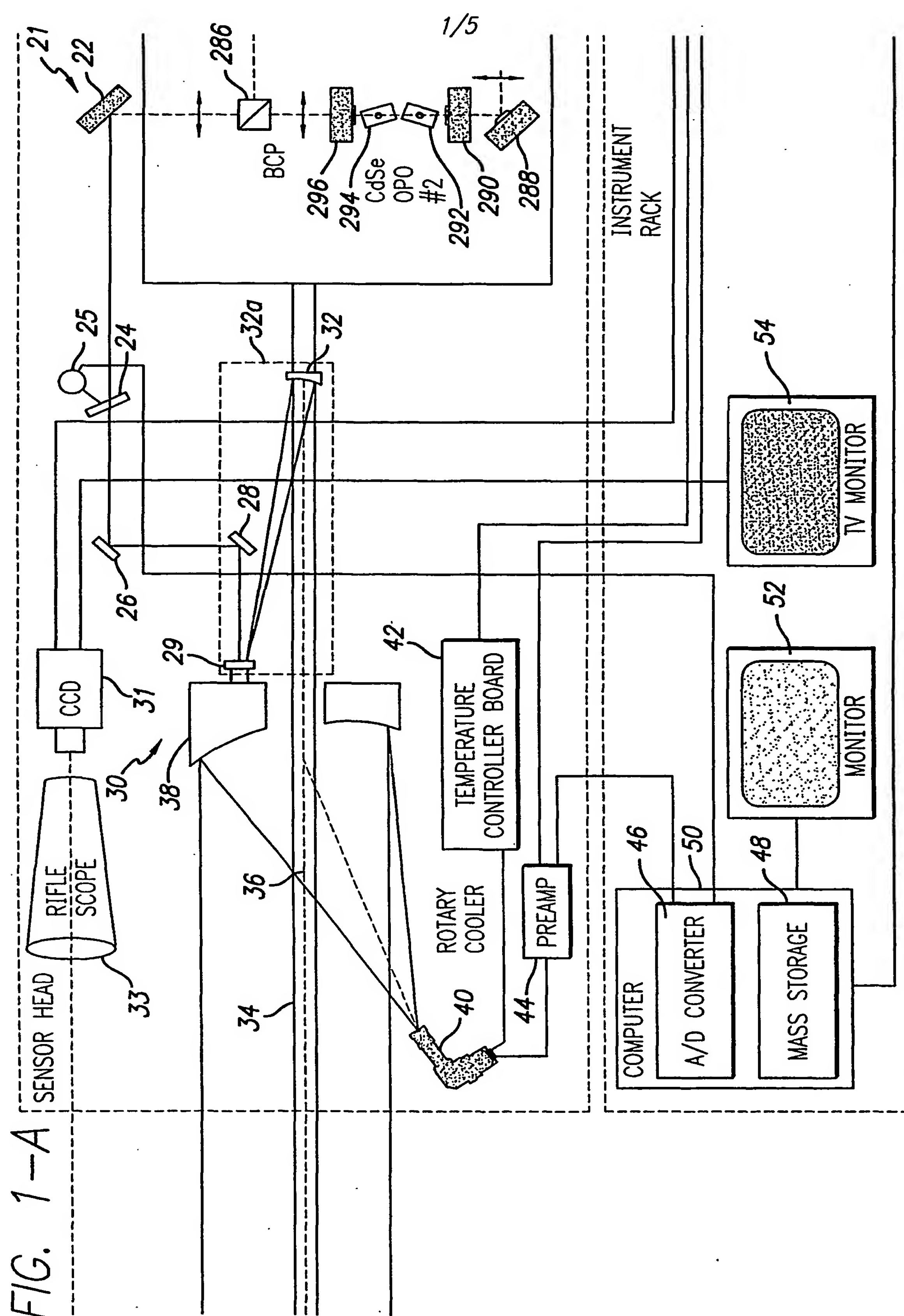
It is therefore intended by the appended claims to cover any and all such applications, modifications and embodiments within the scope of the present invention.

15 Accordingly,

WHAT IS CLAIMED IS:

EUROSTYLE CLAIMS

1. A solid state laser characterized by:
a laser (210) for providing an input beam;
a first oscillator (250) for shifting said input beam from a first frequency to a second frequency, said first oscillator (250) including an optical parametric oscillator;
5 and
a second oscillator (271) for shifting said beam from said second frequency to a third frequency.
2. The invention of Claim 1 wherein said input beam is a one micron beam.
3. The invention of Claim 1 wherein said third frequency is in the range of 8 - 12 microns.
4. The invention of Claim 1 wherein said optical parametric oscillator includes a crystal.
5. The invention of Claim 4 wherein said crystal is potassium titanyl arsenate.
6. The invention of Claim 5 wherein said crystal is X cut.
7. The invention of Claim 1 wherein said second oscillator includes a cadmium selenide crystal.



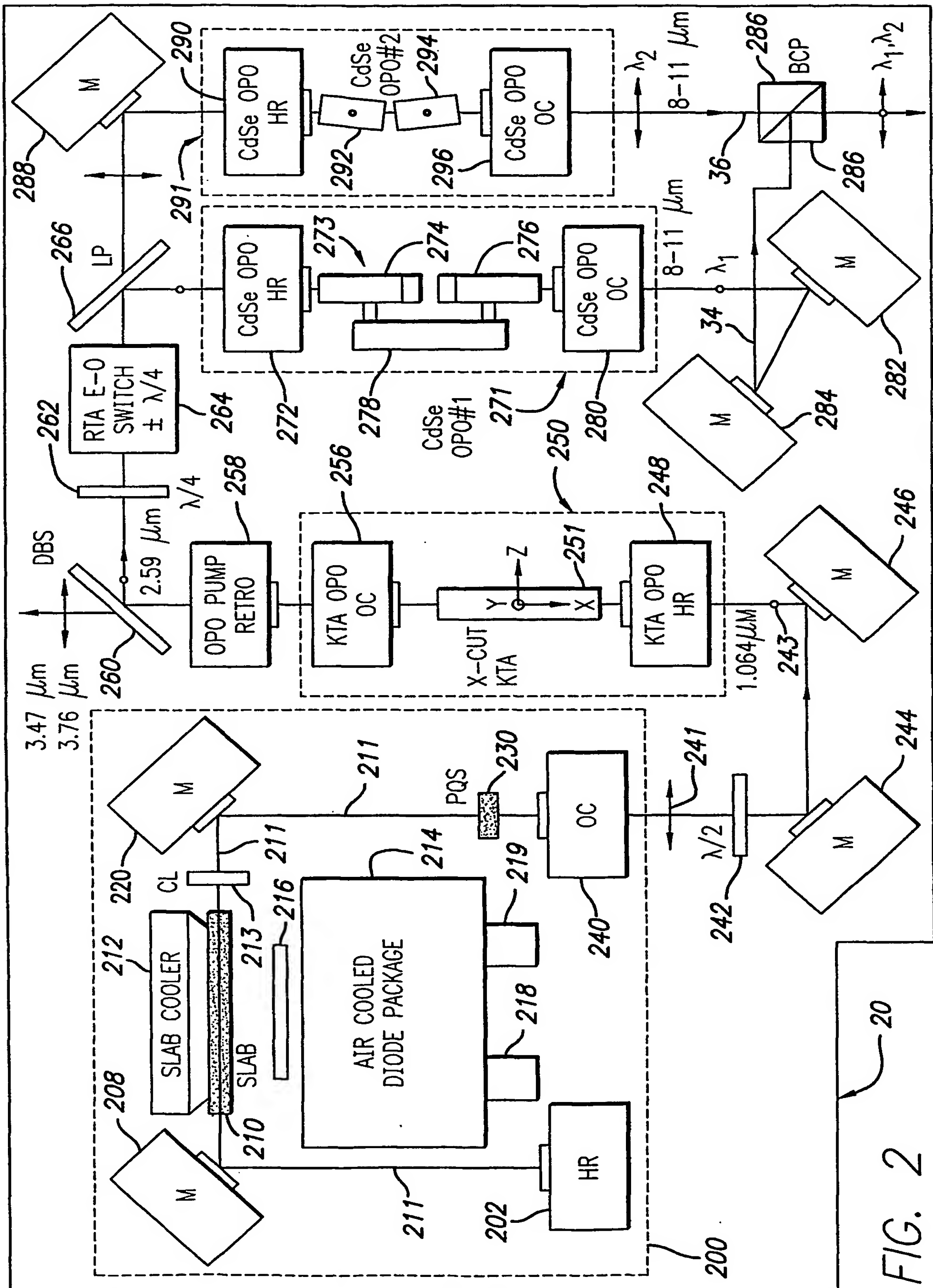
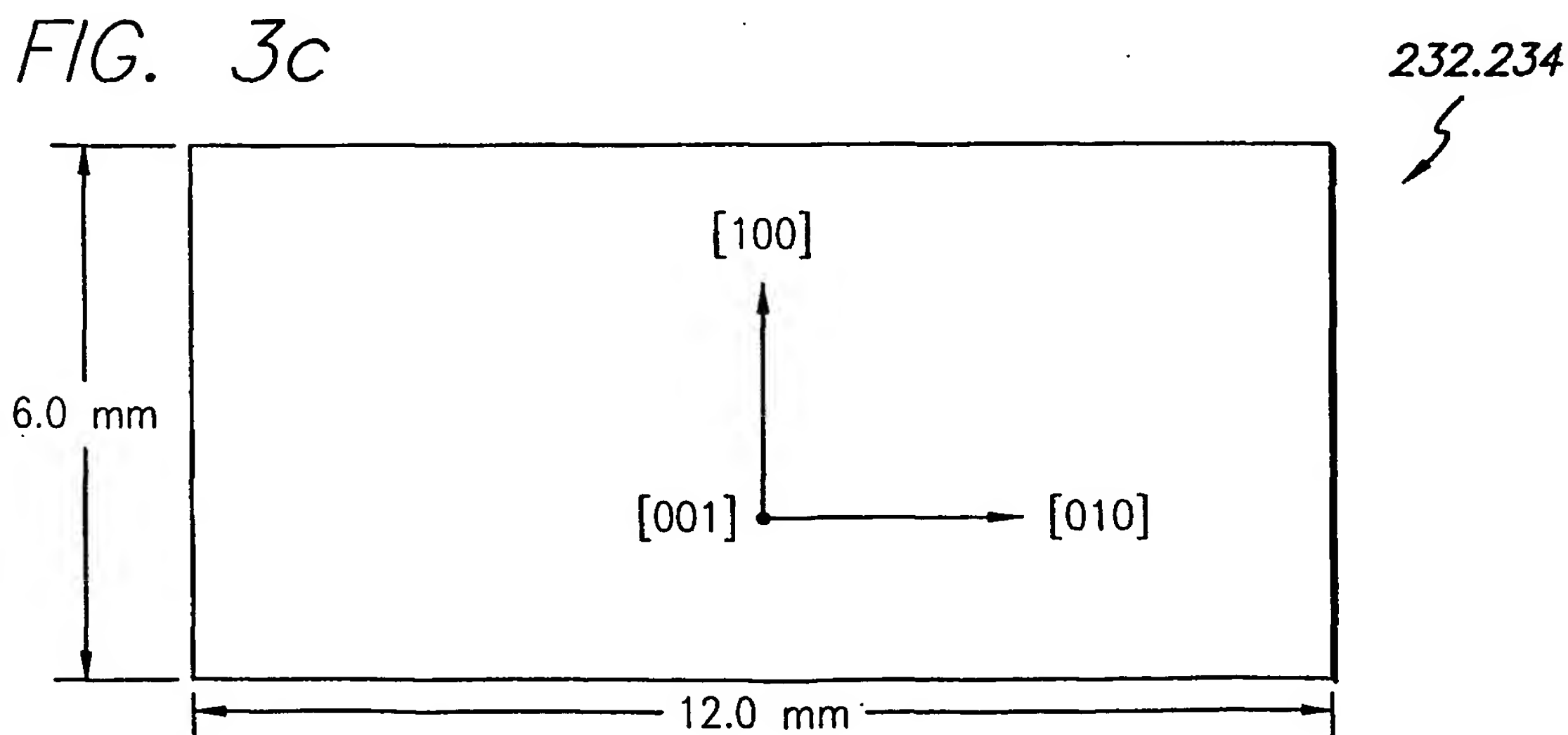
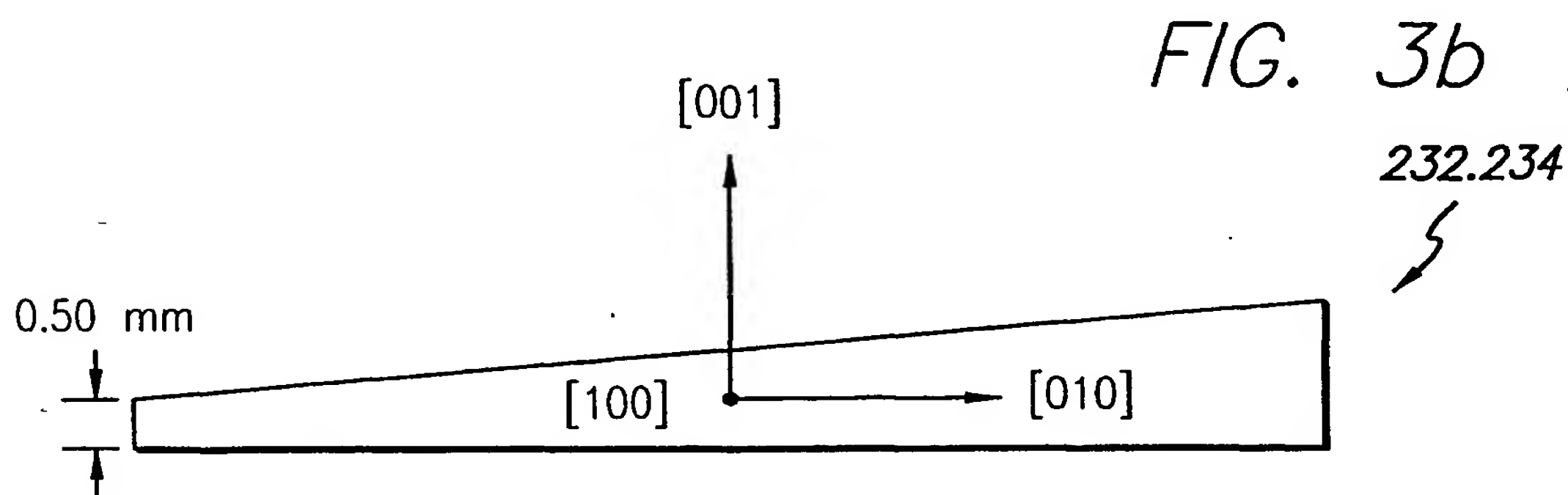
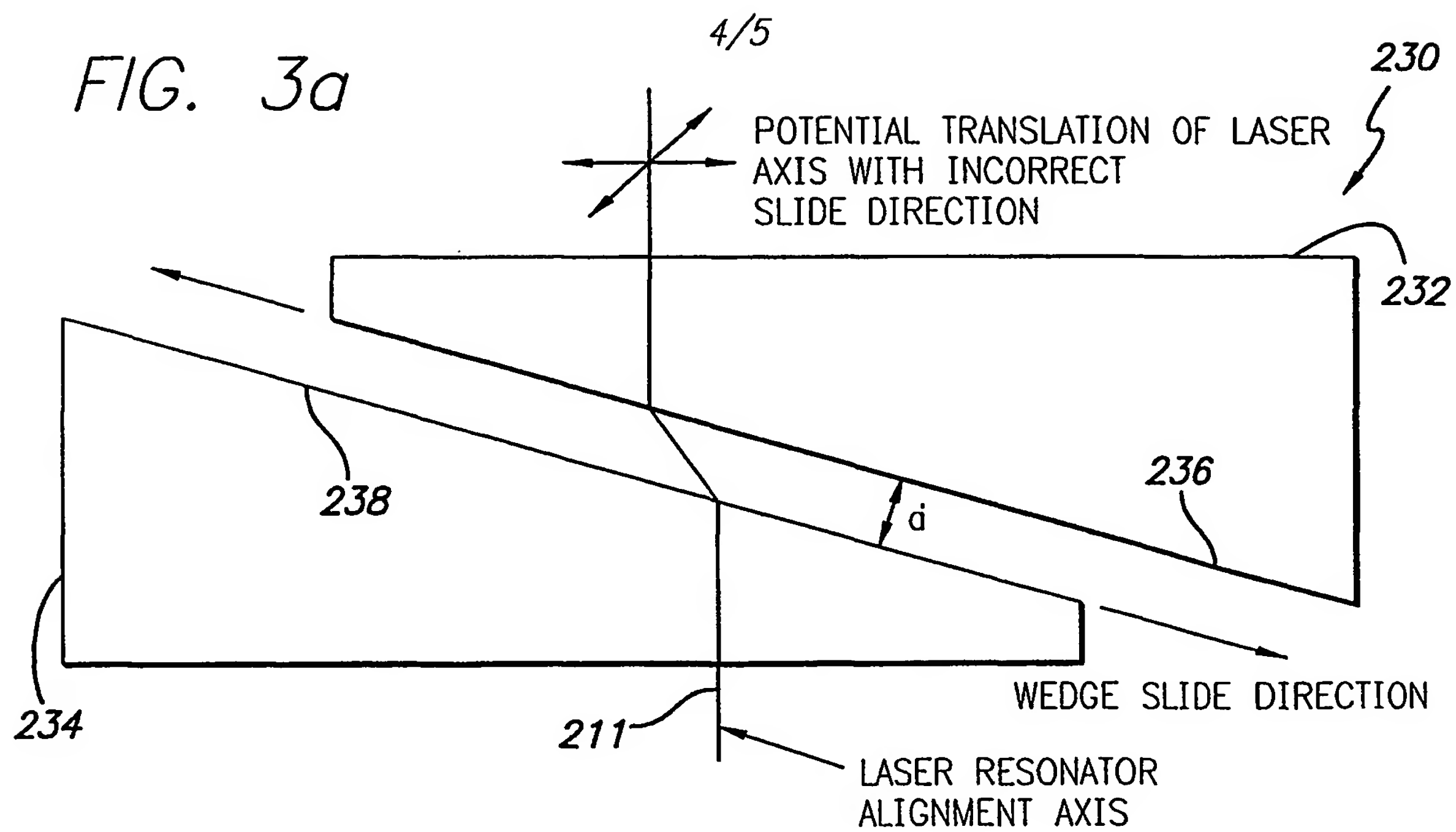


FIG. 2



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FIG. 4

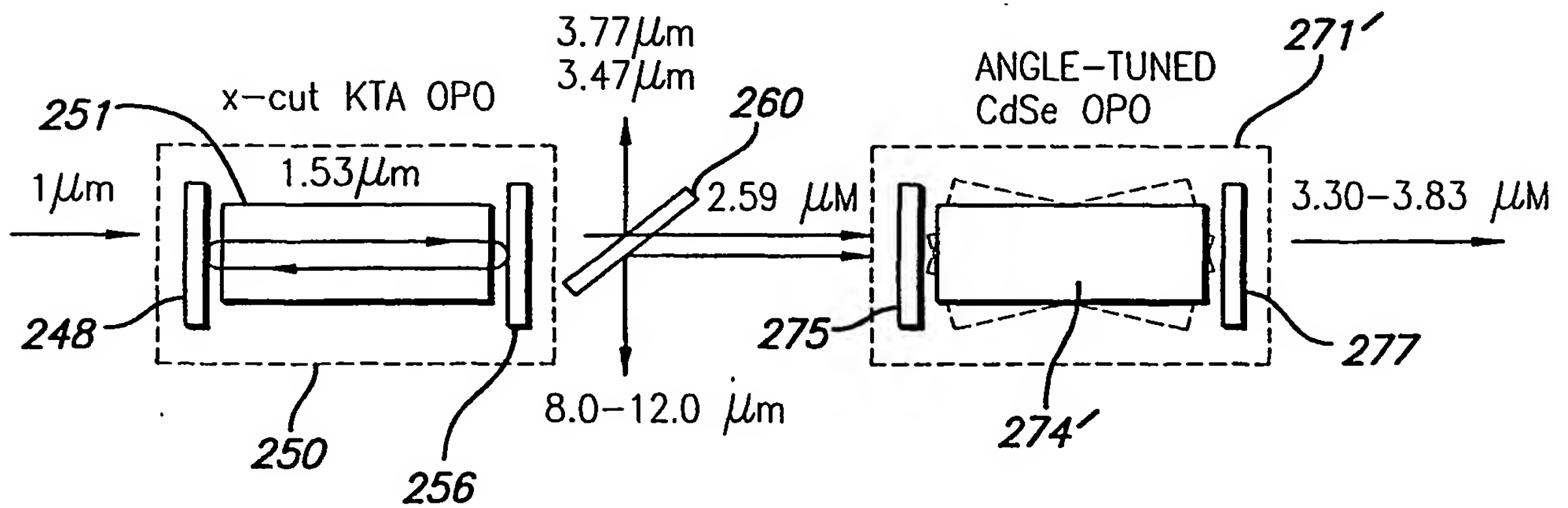
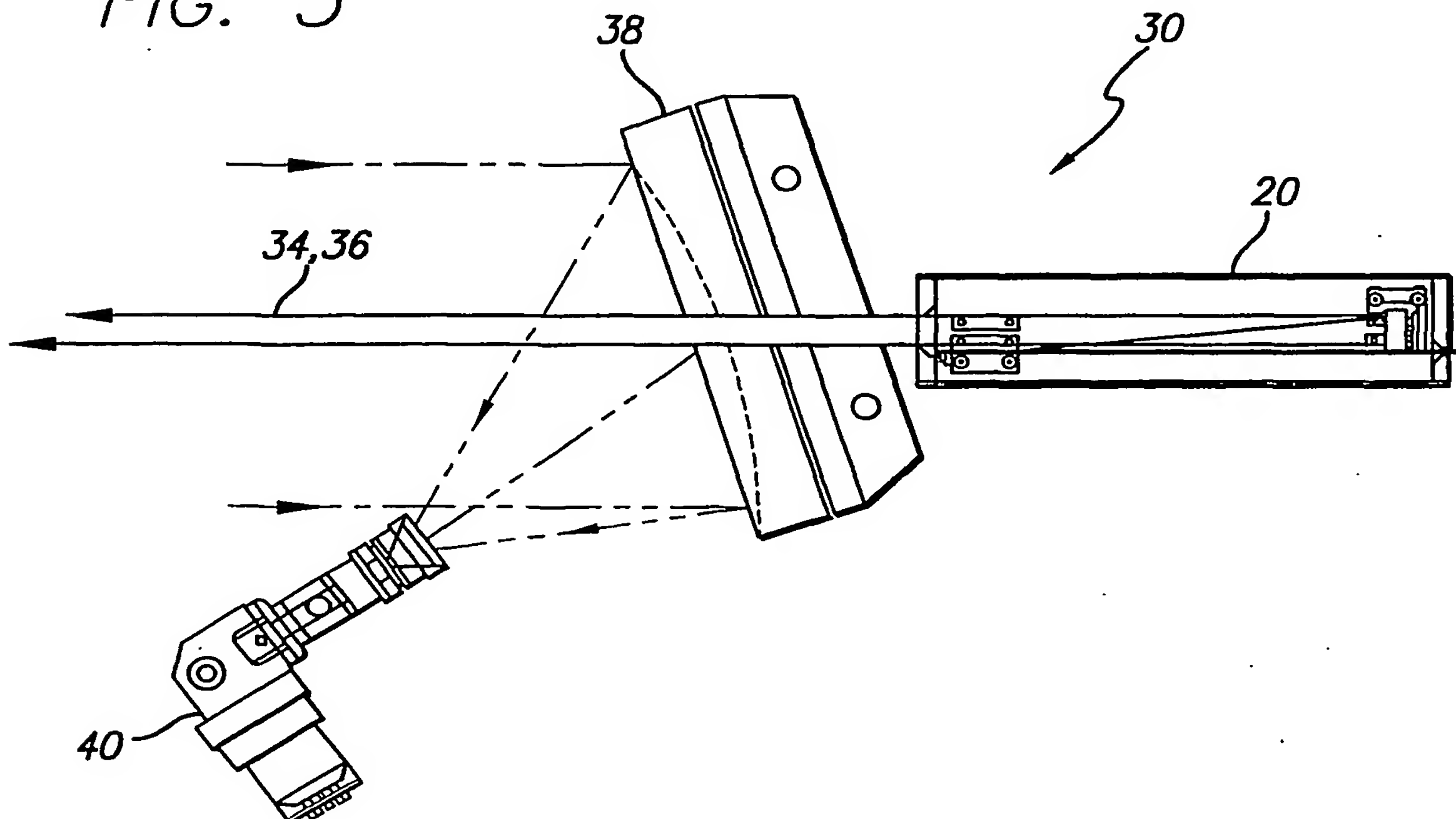


FIG. 5



(19) World Intellectual Property Organization
International Bureau



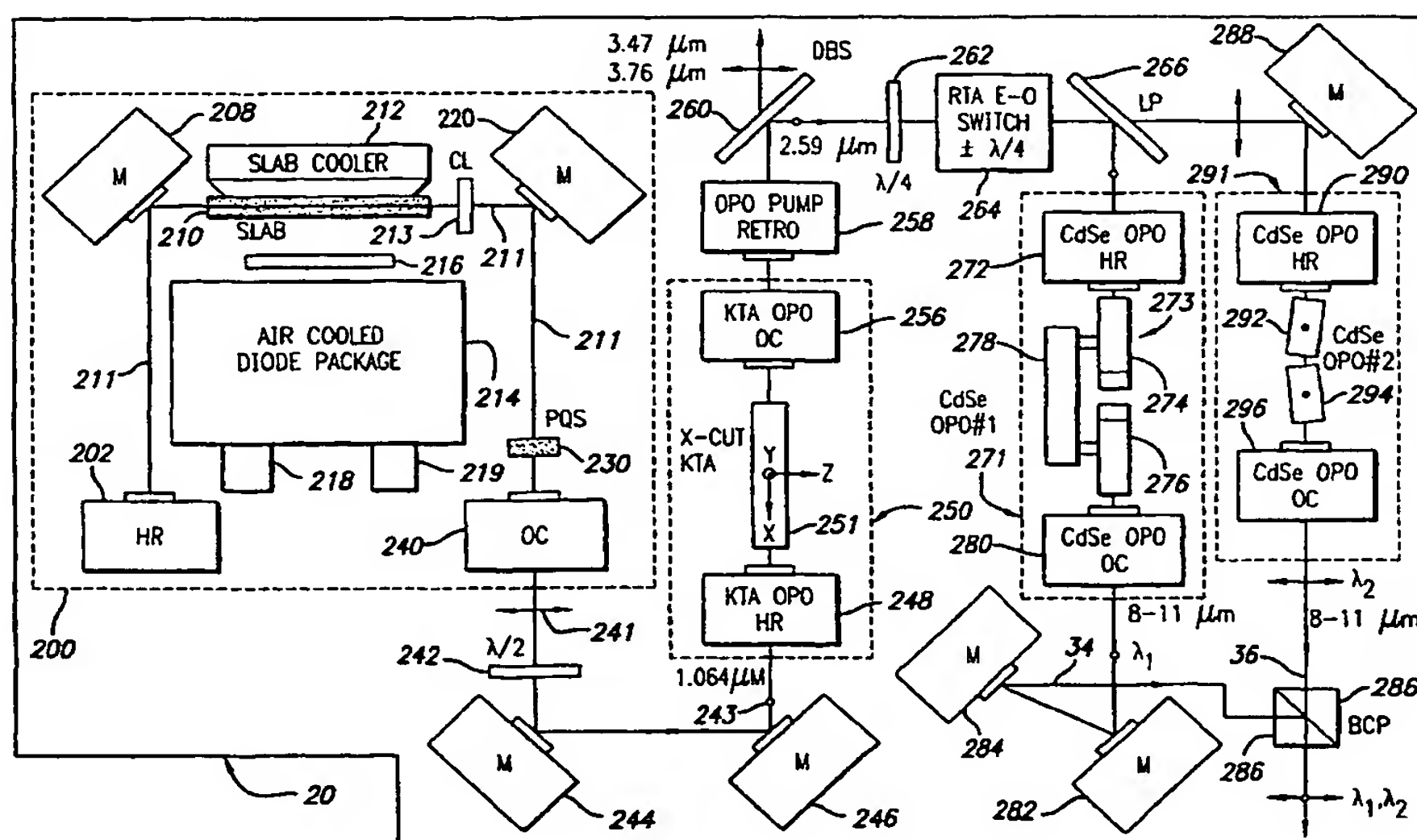
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- (71) Applicant: RAYTHEON COMPANY [US/US]; 2000 East El Segundo Boulevard, P.O. Box 902, El Segundo, CA 90245 (US). (88) Date of publication of the international search report: 4 April 2002
- (72) Inventor: FUKUMOTO, Joseph, M.; 6443 Chartres Drive, Rancho Palos Verdes, CA 90275 (US). For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: 8-12 MICRON RANGE OPTICAL PARAMETRIC OSCILLATOR



(57) Abstract: A novel and efficient system and method for providing an output beam of collimated energy in the 8-12 micron range. The solid state system includes a pump laser (210) for providing an input beam and an OPO (250) using an x-cut potassium titanyl arsenate crystal for shifting the input beam from the first frequency to a second frequency. A second optical parametric oscillator (271) is included for shifting the beam from a second frequency to a third frequency. The second optical parametric oscillator (271) uses a cadmium selenide crystal. A tuning mechanism with an associated controller is provided to tune the oscillator as needed for a particular application.

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INTERNATIONAL SEARCH REPORT

International Application No

PC1/US 01/12048

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G02F1/39

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 5 400 173 A (KOMINE HIROSHI) 21 March 1995 (1995-03-21) abstract column 3, line 51 - line 62 --- -/--	1,2,4-6
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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

17 October 2001

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Galanti, M

INTERNATIONAL SEARCH REPORT

International Application No
PC1/US 01/12048

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>DATABASE INSPEC 'Online! INSTITUTE OF ELECTRICAL ENGINEERS, STEVENAGE, GB; ALLIK T H ET AL: "Advances in optical parametric oscillators with application to remote chemical sensing" Database accession no. 6177201 XP002180001 abstract & ELECTRO-OPTICAL TECHNOLOGY FOR REMOTE CHEMICAL DETECTION AND IDENTIFICATION III, ORLANDO, FL, USA, 13 APRIL 1998, vol. 3383, pages 58-64, Proceedings of the SPIE - The International Society for Optical Engineering, 1998, SPIE-Int. Soc. Opt. Eng, USA ISSN: 0277-786X</p> <p>---</p>	1-6
X	<p>KOMINE H ET AL: "Tunable mid-infrared wavelength converters for neodymium-doped lasers" LEOS '94. CONFERENCE PROCEEDINGS. IEEE LASERS AND ELECTRO-OPTICS SOCIETY 1994 7TH ANNUAL MEETING (CAT. NO.94CH3371-2), PROCEEDINGS OF LEOS'94, BOSTON, MA, USA, 31 OCT.-3 NOV. 1994, pages 177-178 vol.2, XP002180004 1994, New York, NY, USA, IEEE, USA ISBN: 0-7803-1470-0 page 177, line 20</p> <p>---</p>	1,4-6
A	<p>US 4 349 907 A (CAMPILLO ANTHONY J ET AL) 14 September 1982 (1982-09-14) abstract</p> <p>-----</p>	1,7

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 01/12048

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US 4349907	A	14-09-1982	NONE	
